THE PETROLOGY AND ENVIRONMENTAL SEDIMENTOLOGY OF THE SILURIAN STRATA AT HAL-MAR QUARRY

Presented in partial fulfillment of the requirements for the degree of Bachelor of Science in the Department of Geology and Minerology of THE OHIO STATE UNIVERSITY

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Approved by

Advisor

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LIST OF ILLUSTRATIONS

PART I

INTRODUCTION

Purpose And Scope of Investigation

This report presents a detailed description of the Silurian strata observed at THE HAL-MAR STONE QUARRY,Williamsport,Ohio. It attempts to determine the petrology by use of petrographic techniques,insoluble residues,and x-ray,from which the environment of deposition will be determined,and to relate the rock units being studied to Silurian strata already studied to the west (Miller,1955; Butterman,1961;Hellert,1972).

Methods of Investigation

The field work for this report consisted of measuring the section, collecting samples every one foot of section or at distinct lithologic changes, and describing the section in order to divide the strata into distinct lithologic units. Also numerous photographs were taken while in the field to show important features of the area.

Eighteen to twenty samples were studied in the laboratory by insoluble residues,which were given detailed study; by thin sections; and by x-ray diffraction, which was used to determine the calcite-dolomite ratios.

Area Investigated

The area investigated is located in Southern Ohio in the southwesternmost portion of Pickaway County, approximately five miles west of Williamsport, Ohio, on what is considered the western edge of the belt of Devonian outcrop, for the surface bedrock is of Devonian age. This locality has not previously been investigated by workers in the Silurian(Miller, 1955; Butterman, 1961; Hellert, 1972). The Silurian units located here are overlain by Devonian

	Lane, Prosser, Shetzer and Grabau 1909 Mich.-Ohio outcrop	Carmen 1927 Ohio outcrop	Stout 1941 Ohio outcrop	Landes 1945 Mich. subsurface	Calvert 1960 Ohio outcrop	Summerson 1963 Ohio outcrop	Ulteig 1963 Ohio subsurface	Sparling 1965 Findlay Arch region outcrop	Kahle and Floyd N.W. Ohio outcrop 1970
Larger units	Bass Islands Series or Lower Monroe	Monroe Division; Bass Islands Formation	Bass Islands Group; Salina in part ?	Bass Islands Formation (upper); Salina Formation (lower)	Bass Islands Group (upper); Salina Group (lower)	Bass Islands Group (upper); Salina Group (lower)	Bass Islands Group (upper); Salina Group (lower)	Bass Islands Formation; Undifferentiated in W. Cent. and S. W. Ohio (upper)	Tymochtee Formation; Greenfield Formation
	Raisin River	Raisin River Member	Raisin River Formation ?	H Unit	Raisin River Formation	Raisin River Formation	Undifferentiated	Raisin River Member (Ottawa Co.)	Raisin River Formation
	Put-in-Bay	Put-in-Bay Member	Put-in-Bay Formation		Put-in-Bay Formation	Put-in-Bay Formation		Put-in-Bay Member (Ottawa Co.)	Put-in-Bay Formation
	Tymochtee	? Tymochtee Member ?	? Tymochtee Formation ?	G Unit=Tymochtee? F Unit E Unit D Unit C Unit=Tymochtee? B Unit ? —— ?	Tymochtee Formation	Tymochtee Formation	G Unit F Unit E Unit D Unit C Unit=Tymochtee? B Unit	Tymochtee Member (for W.- Cent. & S. W. Ohio) Salina Member (Ottawa Co.)	Roche de Boeuf Member Maumee River Member Ovitt Road Member Granger Island Member
	Greenfield	Greenfield Member	Greenfield Formation	A Unit	Greenfield Formation	Greenfield Formation	Greenfield Formation	Greenfield Member	Undifferentiated

Table 1. Development of the classification of Cayugan strata (Kahle and Floyd, 1971).

formations (figure 1), which make up the western portion of the Appalachian Plateau. The Silurian units are unconformably overlain by the Devonian fossiliferous Columbus Limestone (Chapel, oral communication), which at its base is conglomeratic. The strata dip regionally up to 20 feet per mile in an easterly direction.

Plate I shows the geographic location of the area studied and its position with respect to the geologic formations as seen on the Geologic Map of Ohio (Geologic Survey of Ohio, 1972).

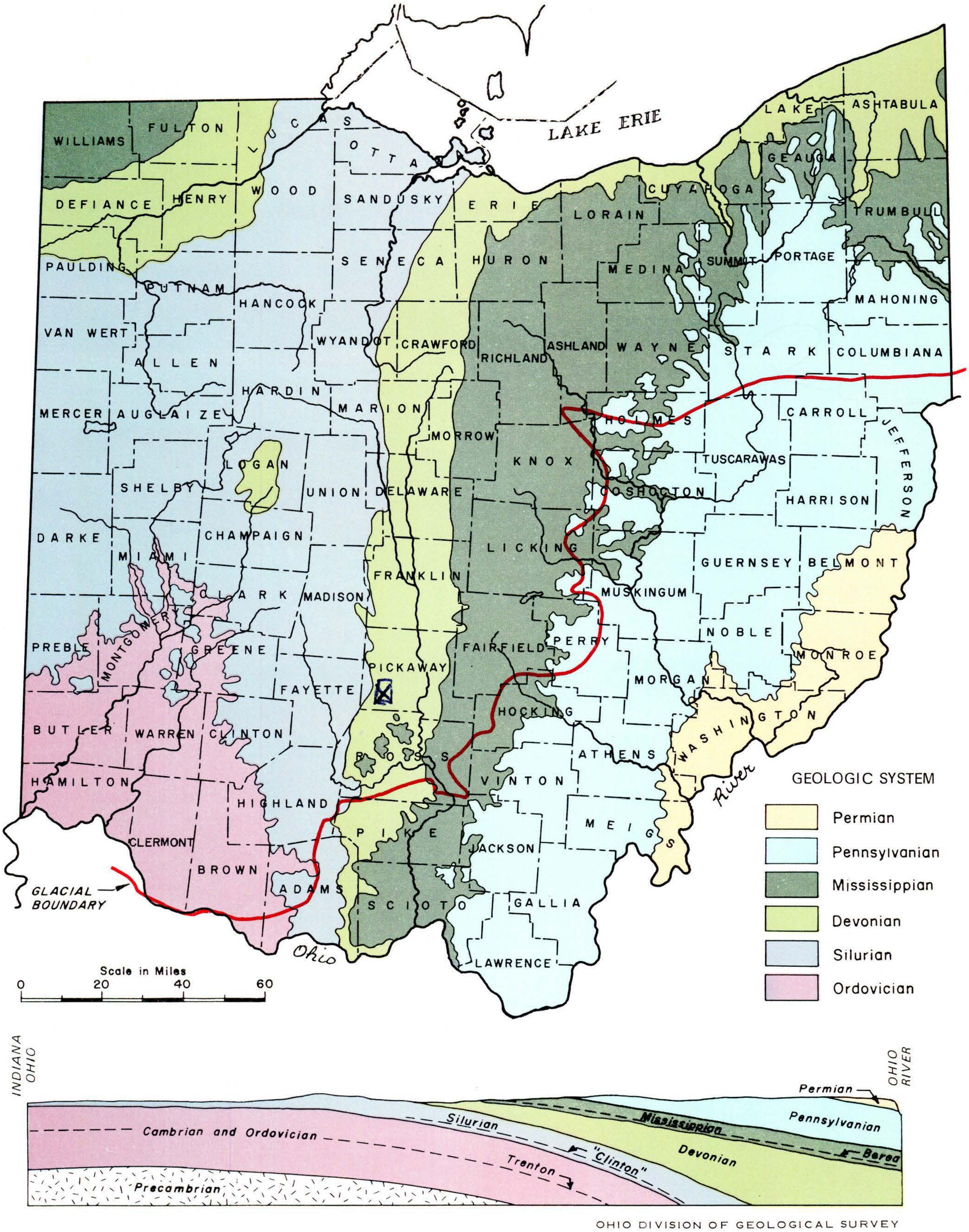
Stratigraphy of the Area

The units studied were of the Cayugan Series which comprises the upper Silurian. These strata are mainly dolomites, which in places are shaley. The names and stratigrphic positions are shown in table 2 which supplies the names of formations present at this locality.

SYSTEM	SERIES	FORMATION
DEVONIAN	ULSTERIAN	OHIO SHALE COLUMBUS LIMESTONE
UPPER SILURIAN	CAYUGAN	RAISIN RIVER DOLOMITE PUT-in-BAY DOLOMITE TYMOCHTEE DOLOMITE GREENFIELD DOLOMITE

TABLE 2. CLSSIFICATION OF CAYUGAN FORMATIONS

The rocks studied could be basically two formations. The strata includes the lowermost portion of the Raisin River Dolomite and the uppermost portion of the Tymochtee Dolomite (figure 1a).



GEOLOGIC MAP AND CROSS SECTION OF OHIO

Approximate Geographical Location

Figure 1. Contact between Silurian Raisin River and Devonian Columbus Limestone

Figure 1a. Tymochtee and Raisin River Dolomites with Columbus Limestone

LABORATORY PROCEDURES

Insoluble Residues

Twenty insoluble residues were prepared from samples , most of which were collected at one-foot intervals, with a few taken from different intervals in order to include distinctive beds.

The manner of preparation of the residues is similar to that described by McQueen(1931,p.105). Aten gram amount of crushed pea-sized fragments from each sample were dissolved in a 16-percent solution of Hydrochloric acid using 250 cc. beakers. After sufficient time (approximately 5 hours) had passed the acid was decanted.

The residues were washed with water and the fine residues were decanted into previously weighed filter papers. The samples were washed more than once in order to remove all fine particles that might cover surface area on the coarse remains; the coarse fractions remained in the beakers . After drying, the fine residues and filter papers were weighed. The coarse residues, after drying, were removed and placed on previously weighed filter papers also and weighed.

The coarse residues were then examined under the binocular microscope.

Thin Sections

Rogers and Kerr (1942,pp. 3-7) have described the prepartion of thin sections; a few changes were made in their procedure. The chips were obtained by cutting 40 mm-by-20mm pieces from slabbed samples on a DI-MET FELKER trim saw(DI-MET FELKER MFG. CO., Torrence, Calif.). These chips were then ground down, first with 400 carborundum on a grinding wheel and then with 600 carborundum on a glass plate. These smoothly ground chips were then mounted on 45mm-by-26mm glass slides with Canada Balsam and cut with a thin-section saw(Ingram Laboratory Inc.,Griffin, Georgia), ground with a thin-section grinder, and given final grinding by hand with 600 carborundum.

X-Ray Diffractions

X-ray samples were prepared by crushing a small piece of sample with a mortar and pestle, then making a smear slide. The smear was made by taking a small amount of crushed sample and combining it with a solution of duco cement and acetone, then smearing this on a 45mm-by-26mm glass slide. These prepared slides were then analyzed by a GENERAL ELECTRIC X-RAY DIFFRACTOMETER with Cu K Alpha radiation. The range of the analses was from 10 degrees two theta to 40 degrees two theta. Fifteen samples were studied by this method.

PART 2
RAISIN RIVER FORMATION
Stratigraphy

The Raisin River Dolomite has a thickness of 20 to 25 feet. This formation can be divided into four distinct units which will be referred to as A-1, denoting uppermost unit, through A-4. Overall this formation is a greyish-brown massive argillaceous dolomite, containing abrecciated zone in the A-3 and A-4 units.

Unit A-1 is a brownish-grey, fine-grained massive dolomite containing uneven laminations and some breccias. This unit is approximately 5 feet thick throughout the exposure.

Unit A-2 is a greyish massive argillaceous dolomite having an irregular knobby surface with lenses of chert and styolites (figure 2). Also there are small cavities with quartz crystals. Unit A-2 is approximately 5 feet thick.

Unit A-3 is a brownish-grey laminated, fine-grained, dense, brecciated, argillaceous dolomite. The breccias appear to have been formed before deposition and consolidation of the dolomite. They are discontinuous with discontinuous finely laminated dolomite (figure 3) between each two breccia mounds (figure 4). These breccias are compact and well cemented; they have clotted dark surfaces with a finer lighter matrix. They are approximately 5 feet in diameter. Unit A-3 is approximately 10 feet thick, but thickness varies in the exposure.

Unit A-4 is a greyish, fine-grained, argillaceous massive, brecciated dolomite containing mounds which may be due to stromatolites, and numerous carbonaceous partings. These mounds contain tiny cavities with crystals of quartz. Unit A-4 is tightly cemented as Unit A-3 and varies in exposed thickness from 5 to 10 feet.

The Raisin River is fairly unfossiliferous, although a few gastropod molds were found in the brecciated mound horizons. This lack of fauna may

Figure 2. Styolites in Raisin River Dolomite (Unit A-2)

Figure 3. Finely laminated dolomite in brecciated horizon (Unit A-3).

be due in part to two causes. First, the circulation in the sea at the time was probably restricted and evaporation created a hypersaline environment in which no animals could exist. Second, dolomitization may have destroyed any fossil shells and structures through recrystalization, which would leave no evidence of their origonal form.

Figure 4. Brecciated mound in Unit A-3
Raisin River Dolomite

PETROGRAPHY

Insoluble Residues

Insoluble residues were obtained from 15 samples. The total residue from all samples was eight percent by weight, but in most of the sampleswas less than six percent.

The proportion of fine to coarse residue is very small, the fine residue making up 5.0 percent of the weight of the origonal sample, or 61.0 percent of the total residue, on the average. The fine fraction consisted mainly of clay-sized particles. This part of the residue was only studied for weight percentages because most clays break down in slight concentrations of acids (Grim, 1953 p. 296).like those in the preparation of these residues.

The coarse residues were composed of fine silts, containing mainly quartz, with minor amounts of pyrite, hematite, limonite, and some sand-sized grains. The quartz made up the major portions of the residues in all samples.

Quartz composed over 65.0 percent on the average of the coarse residues. Authigenic and detrital quartz is present in most residues in sand-sized aggregates(1/16mm to 1/4mm) of quartz which are cemented by silica cement. The grains of quartz are subangular to subrounded and the surfaces are microfaceted and slightly frosted. The average grain size is in the coarse silt range(1/32mm to 1/16mm).

Euhedral quartz crystals were observed in five of the residues. These occurred as loose coarse silt to fine sand-sized crystals. Also many subhedral crystals of quartz were observed, ranging from 1/32mm to 1/4mm in size.

Silt grains were the second most abundant element found in the residues. Sizes ranged from a medium to coarse grade. The grains were generally subangular to subrounded. In almost all of the samples, grains formed sand-sized clusters of crystals, these grains in the clusters being microfaceted and lightly frosted.

Varying amounts of pryite were present in the samples, occurring as tiny disseminated crystals in irregular masses with many faces. On the average these occurred as medium and coarse silt-size grains, but some sand-size grains(1/16mm or greater) of pyrite were also observed.

In five of the samples there traces of flakey fragments of hematite, of silt- and sand-size. Limonite was also observed, as a coating around altered grains.

Thin Sections

Study of the thin sections of the Raisin River showed very little except for the nature of its texture. In a few thin sections, grains of detrital quartz were observed. Minor impurities occurred in such minute proportions that recognition of them in thin section was very difficult. The major constituent is dolomite. The texture of all the thin sections studied are basically the same.

The texture of the Raisin River is a mosaic of anhedral dolomite which is very fine grained. The grain sizes range from 2 to 8 microns, the average around 6 microns. The dolomite grains are typically equi-dimensional. Boundaries between grains are generally angular; a few are sutured and micro-styolitic. The distinct cleavage was not observed in any of the thin sections. Also there were no zoned dolomites or twinning seen in any thin sections. Many of the thin sections contained organic matter which separated grains.

The occurrance of clastic quartz, which is subangular to subrounded, may be due to the origin of the sediment. The size of the quartz, approximately 4 microns, and lack of other clastic features suggests that the quartz was wind blown.

The argillaceous and organic materials are generally found in thin partings which form thin laminae in the rock. Generally these partings are slightly irregular, but a few are styolitic. The styolites were found also to contain some hematite and some quartz. The quartz grains are equidimensional, on the average .06mm. and subangular to subrounded.

Also it was noted that some of the thin sections contained pellets, which were grumulose; clasts, which were banded and usually coarser grained, about .1mm ; and oolites, which were oval-shaped. Also in a few slides there were veins containing hematite and quartz, the latter being chalcedonic in places. There were also minor constituents of pyrite and limonite.

The oolites observed are generally oval-shaped but some are elongate. The size range is from .08mm to .26mm. These have no radial or concentric structure. The outer part is defined by a dark rim which may be composed of carbonaceous or argillaceous material. The interiors contain dolomite that is subhedral.

The clasts are composed of very fine-grained dolomite. They are subrounded and composed of dolomite with minor amounts of pyrite. These ranged in size from .25mm to .4mm.

The petragraphy of these thin sections is of a fine-grained dolomite which are uniform micrites and contain micritic intraclasts, some laminated and some styolitic.

X-Ray Diffractions

The x-ray diffractions were originally run todetermine the calcite-dolomite ratios. However, no calcite was found in any of the samples tested. The x-rays showed that the rocks contained 88.0 percent dolomite, on the average, the rest being quartz, and some feldspars in small amounts.

PART III

TYMOCHTEE FORMATION

Stratigraphy

The Tymochtee Dolomite can here be described as grey to drab, dense, thin-bedded, laminated, and argillaceous, with some shaley partings and thin layers of carbonaceous material. The beds are from 2 to 6 inches thick and have irregular bedding surfaces. This is a very fine-grained and dull dolomite. The Tymochtee is exposed approximately 7 feet. The exposure is inaccessible, however, for it is across a 40 foot deep, water-filled sump(figure 5). The samples collected from the Tymochtee were from blocks excavated from the simp. These samples were inferred to be of the Tymochtee Formation because of the presence of shaley partings, which is indicative of the upper Tymochtee (Summerson, oral communication).

Fossils are notably limited in this formation, ostracodes(Leperditia, sp.) and gastropodes(Solenospira(?),sp.) were observed, but few. Here dolomitization could have destroyed most fossil fragments and structures by recrystallization.

Sedimentary structures were found to be abundant. These included mudcracks, ripple marks, feeding trails, evaporite crystal molds, and burrows, some of which have been replaced by pyrite (see figures 6-19). Also found in a small amount were gypsum crystals. These structures and lithologies tend to indicate a shallow hypersaline environment.

Figure 5. Exposed portion of Tymochtee Dolomite

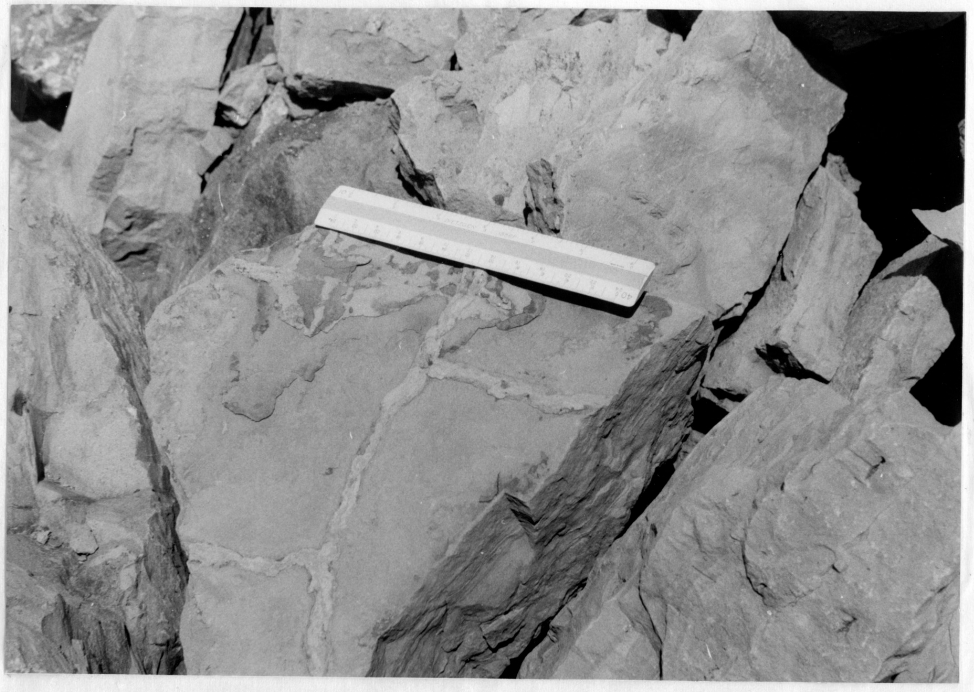


Figure 6. mudcracks in upper Tymochtee

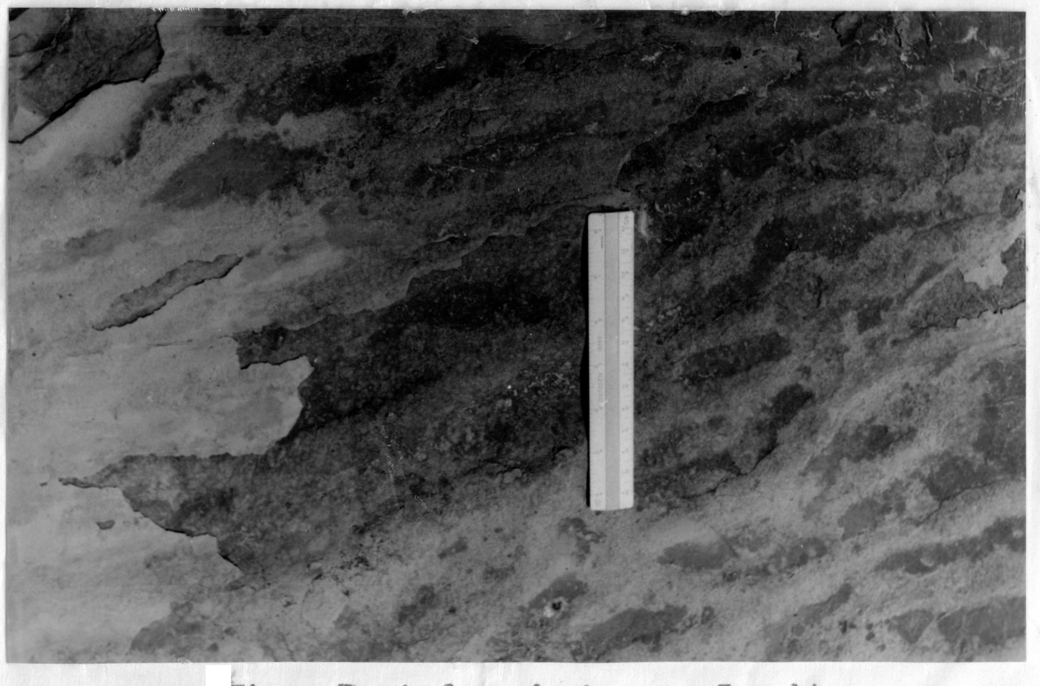


Figure 7. ripple marks in upper Tymochtee

PETROGRAPHY

Insoluble Residues

The insoluble residues were obtained from four samples of the Tymochtee Dolomite. From the total residue of the samples it was found that they comprise 16.0 percent of the total weight of original sample. The fine residue made up 8.3 percent of the weight of the total sample, thus comprising 24.3 percent of the total residue. The fine residue consisted of clay-sized particles and was used only for weight percentages.

The coarse fractions of the residues consist of fine silts, quartz, pyrite, minor constituents of hematite, and limonite, in order of decreasing abundance.

The major portion of the residues is fine silt-size quartz, and clay. These particles could represent terrigenous clastic sediments. Many of the agglomerates are finely porous, which might suggest penecontemporaneous deposition of carbonates. The color of the silts range from a medium grey to a tan. The grains are of a fine- to medium-silt size(1/128mm to 1/32mm).

Quartz is not as abundant in these residues as in the Raisin River. Most of this ranges from 1/32mm to 1/4mm in size. The greater portion are subangular to subrounded, some are rounded, and have frosted surfaces. Euhedral quartz was observed in two of the samples.

Pyrite occurs as tiny crystals of approximately 1/8mm to 1/4mm in size and as irregular clusters which are 1/4mm to 1/2mm in size. In many the pyrite is coated with limonite from alteration.

Minor amounts of hematite are present, as flakey fragments 1/8mm to 1/4mm in size. Limonite was present as alteration coating on some of the silt grains.

The relative lack of quartz aggregates in the Tymochtee seems to be the only distinguishing dissimilarity between this formation and the Raisin River residues. However the Tymochtee is somewhat more argillaceous.

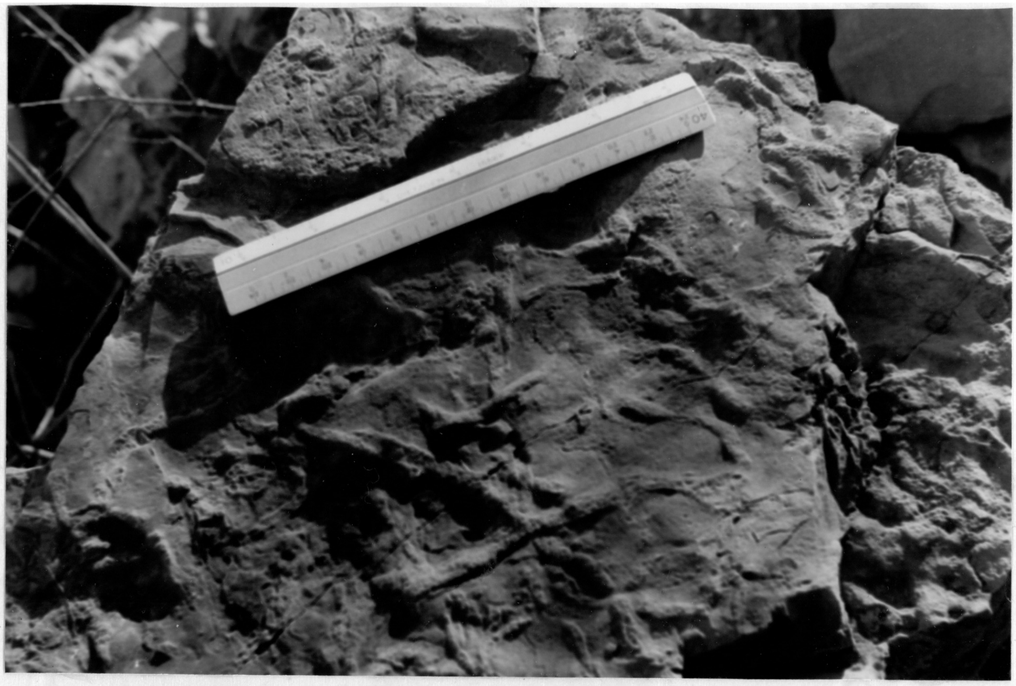


Figure 8. feeding trails in upper Tymochtee

Figure 9. Aligned evaporite crystal molds

Thin Sections

The thin sections of the Tymochtee Dolomite revealed little additional information about the unit. There was some detrital quartz and some pyrite present, with the major constituent being fine-grained dolomite. There were also oval-shaped pellets composed of pyrite and dolomite.

The texture of these rocks was extremely fine grained. Grain sizes ranged from 1 to 8 microns, with an average of 6. The dolomite forms an interlocking mosaic of anhedral and subhedral crystals. There was argillaceous material throughout the interlocking framework of grains. The grain boundaries are sutured and angular.

The quartz present was subrounded, which again suggests a wind-blown sediment. The grain sizes range from .04mm to .09mm.

Pyrite is present, occurring in oval-shaped pellets and also in rounded masses, the latter are most likely the parts of a pyritized burrow. The pellets are grumulose in appearance and approximately 2mm in size.

These thin sections may all be described as fine-grained dolomites containing pellets.

X-Ray Diffractions

From the smeared slides of the Tymochtee that were x-ray analyzed, it found that no calcite was present. These samples were composed mainly of dolomite, averaging 83.0 percent of the rock, with quartz, pyrite, and minor amounts of feldspars and gypsum constituting the remainder of the rock.

PART IV

CONCLUSIONS

Sedimentation of the Raisin River Dolomite consisted of carbonate deposition in fairly clear hypersaline shallow water on a shelf platform. This shelf region is thought to have been situated between open seas, one to the east and one to the south, and restricted by a sea in the Michigan Basin(Sparling, p.27). The high salinity is suggested by the lack of fauna. With such a high salinity the environment would have been so adverse that only a few species of animals could survive. Shallow conditions are suggested by the presence of oolites and breccias.

The brecciation of the Raisin River is its most striking sedimentary feature. These breccias are discontinuous but occur at regular intervals. The breccias were probably formed by dessication which was caused by retreats of the sea, which, because of the size of the breccias, implies a short duration of time and a low magnitude.

It is suggested, then, by shallow water and dessication features that these rocks were deposited in a shallow sea which had periods of subarial exposure. Thus, with evaporation taking place there would be an increase in the concentration of magnesium, allowing more of the carbonate sediment to become dolomitized.

The Tymochtee Dolomite most probably was formed in a shallow marginal area of an extensive evaporite basin. Such basins were created by the restriction water circulation by shallow banks. High salinity prevailed in the sea at this time, this is indicated by the presence of evaporite crystal molds. Salinity was low enough at times, however, to support ostracodes(Leperditia, sp.) and abundant algal life. These periods of low salinity probably were caused by enormous storms which decreased the salinity.

The above and the presence of sedimentary structures, mudcracks, ripple marks, and evaporite crystal molds, are indicative of deposition in a shallow water environment, in which there periods of drying. This is also suggested by the presence of pellets in the dolomites, burrowings, and the lack of well-preserved fauna. This formation was deposited in a shallow upper continental sea where circulation would be restricted and in which there were periods of emergance and dessication.

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